3.9 GEOLOGY, SOILS, AND SEISMICITY

INTRODUCTION

This section describes the geology, soils, and seismicity in the SCAG region, identifies the potential impacts of these conditions on projects considered in the 2004 RTP, including mitigation measures for these impacts, and evaluates any residual impacts that would remain, subsequent to mitigation.

ENVIRONMENTAL SETTING

Topographic and Geologic Structures

Portions of the SCAG region extend over four geomorphic provinces (natural regions) of California. These provinces, depicted in Figure 3.9-1 (see the Figure Chapter at the end of this document), are referred to as the Mojave Desert, the Transverse Ranges, the Peninsular Ranges, and the Colorado Desert. [1]

Mojave Desert

The Mojave Desert geomorphic province occupies approximately 25,000 square miles. It is bounded by the San Andreas fault and the Transverse Ranges to the west, the Garlock fault and the Tehachapi Mountains to the north (in Kern County), the Nevada State line to the east, and the San Bernardino/Riverside County boundary to the south. Portions of Los Angeles and San Bernardino Counties lie within this province.

Erosional features such as broad alluvial basins that receive non-marine sediments from the adjacent uplands dominate the Mojave Desert region. Numerous playas, or ephemeral lakebeds within internal drainage basins, also characterize the region. Throughout this province, small hills—some the remnants of ancient mountainous topography—rise above the valleys that are surrounded by younger alluvial sediments. The highest elevation approaches 4,000 feet above sea level (asl), and most valleys lie between 2,000 to 4,000 feet asl.

Transverse Ranges

The Transverse Ranges geomorphic province is a series of east-west trending mountain ranges and broad alluvial valleys that extend approximately 320 miles from Point Arguello in the west to the Little San Bernardino Mountains at the edge of the Mojave and Colorado Desert provinces in the east. This geomorphic province includes Ventura County and portions of Los Angeles, San Bernardino, and Riverside Counties.

[1] The Basin Range province covers the northwest corner of San Bernardino County.

Prominent basins and ranges in the Transverse Ranges include the Ventura basin and the San Gabriel and San Bernardino Mountains. Several active faults, including the San Andreas Fault Zone, are located in the Transverse Ranges. Faults in the province include the Santa Clara River Valley fault, the San Gabriel Fault Zone, the Santa Cruz Island faults, the Santa Rosa Island Faults and the Soledad faults. This province is one of the most geologically diverse in California, containing a wide variety of bedrock types and structures. The Transverse Ranges include California's highest peaks south of the central Sierra Nevada and the only Paleozoic rocks in the coastal mountains in the United states. The province is subdivided into ranges and intervening valleys. Broad alleviated valleys, narrow stream canyons, and prominent faults separate these ranges.

Peninsular Ranges

The Peninsular Ranges geomorphic province extends from the Transverse Ranges to deep within Mexico, passing through the Los Angeles Basin and continuing 775 miles south of the US-Mexico border. The Peninsular Ranges are bounded on the west by the Transverse Ranges and on the east by the Colorado Desert, and include Orange County and the San Jacinto Mountains and the Coachella Valley in the central portion of Riverside County. The ranges are comprised of a series of northwest-southeast trending mountains that are separated by several active faults, including the San Jacinto and Elsinore Fault zones.

The Peninsular Ranges is one of the largest geologic units in western North America. Its highest elevations are found in the San Jacinto-Santa Rosa Mountains, with San Jacinto Peak reaching 10,805 feet asl. The orientation and shape of the Peninsular Ranges is similar to the Sierra Nevada, in that the west slope is gradual and the eastern face is steep and abrupt. Drainage from the province is typically by the San Diego, San Dieguito, San Luis Rey and Santa Margarita rivers.

Colorado Desert (Salton Trough)

The Colorado Desert geomorphic province (also referred to as the Salton Trough) is bounded to the east by the Colorado River, to the south by the Mexican border, and on the west by the Transverse Ranges. This province includes Imperial County and eastern Riverside County. The Colorado Desert trends northwesterly-southeasterly, as do most geologic provinces in Southern California. The San Andreas Fault system is prominent in the northeast side of the Salton Trough. The Colorado desert lies at low elevation, as compared with the Mojave Desert province, ranging from the Colorado River Valley, at approximately 350 feet asl, to the Salton Basin, at 235 feet below sea level. Its geologic features include playas separated by sand dunes and the Salton Trough, a large structural depression that extends from Palm Springs to the Gulf of California.

Soils

Soils within the SCAG region are classified by distinguishing characteristics and are arranged within soil associations. Soils throughout the region differ in origin, composition, and slope development. The individual soil characteristics are key in determining the suitability of the soil for agricultural use or for urbanized development.

The formation of surficial soil depends on the topography, climate, biology, local vegetation, and the material on which the soil profile is developed. Although many soils in the SCAG region are suitable for agricultural uses, each soil type may have properties that could limit its uses and represent an agricultural or development hazard.[2] These limitations are listed and discussed below. Figure 3.9-2 (see the Figure Chapter at the end of this document) maps the general location of soil types contained within the SCAG region. Applicable U.S. Department of Agriculture Natural Resource Conservation Service (USDA-NRCS) soil surveys for specific counties provide the classification and description of each soil type encountered in the SCAG region. Figure 3.1-6 (see the Figure Chapter at the end of this document) contains the general location of areas considered prime or important farmlands.

Seismicity

The SCAG region is located in an area that has historically experienced high seismicity. In the past 100 years, several earthquakes of magnitude 5.0 or larger have been reported on the active San Andreas, San Jacinto, Elsinore, and Newport-Inglewood fault systems, all of which traverse the SCAG region. As a result, significant earthquake hazards exist in the region.[3] Injury to people and damage to structures during earthquakes can be caused by actual surface rupture along an active fault, by ground shaking from a nearby or distant fault, liquefaction, or dam failure. In Southern California, the last earthquake exceeding Richter magnitude 8.0 occurred in 1857. Much more frequent are smaller temblors, like the relatively moderate (but still exceedingly damaging) 1971 San Fernando and 1994 Northridge earthquakes, both classified as magnitude 6.7 quakes.[4]

Regional Faults

A fault is a fracture in the crust of the earth along which there has been displacement of the sides relative to one another parallel to the fracture. Most faults are the result of repeated displacements over a long period of time. Numerous active and potentially active faults have been mapped in the region.

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[2] United States Department of Agriculture, Soil Conservation Service (SCS). 1970. *Soil survey of ventura area, California.* Issued April, 1970.

[3] It should be noted that new faults continue to reveal themselves, such as in the case of the Northridge earthquake of 1994, and the potential seismic threats posed by these faults also continue to be reevaluated on the basis of new geologic information and analysis, as in the recent case of the Puente Hills Fault [Dolan et al., 2003; McFarling, 2003].

[4] The human and economic damage caused by earthquakes tends to increase with time, as more and more people and property come to occupy more and more of the land, thus cumulatively increasing the exposure of human habitation to seismic hazard. The 1994 Northridge earthquake, though hardly the most severe experienced by Southern California, was deemed the most expensive, in terms of its economic cost and its damage to human property. The California Office of Emergency Services claimed a $15 billion total damage estimate [EQE International, 1994].

The SCAG region contains lateral strike slip faults similar to the San Andreas and various identified and hidden blind thrust faults. A fault trace is the surface expression of a particular fault. Buried or blind thrust faults are thought to underlie much of the SCAG region. These "buried" faults do not exhibit readily identifiable traces on the earth's surface and are typically at considerable depth within the underlying geologic formation. Although these faults typically do not offset surface deposits, they can generate substantial ground shaking.

The CGS defines active faults as those that have exhibited evidence of displacement during Holocene (10,000 years ago to present) period. Potentially active faults are defined as faults that have exhibited evidence of displacement during the Pleistocene period (10,000 years to 1.8 million years ago). Class A faults have slip rates greater than 5 millimeters per year (mm/yr) and generally have substantial historic seismic data available, while Class B faults have slip rates smaller than 5 mm/yr and, as a rule, historic seismic data on which to develop reliable recurrence intervals of large events is lacking.

Table 3.9-1 characterizes the major faults in the SCAG region. Figure 3.9-3 (see the Figure Chapter at the end of this document) illustrates the geographic location of these faults in the region.

Geologic Hazards

Potential geologic hazards include expansive soils, settlement, subsidence, and erosion. Relevant geologic hazards applicable to the SCAG region are discussed below. These conditions are important with respect to transportation, as they may pose hazards that can affect operation of facilities or can constrain system development.

Expansive Soils

Expansive soils possess a "shrink-swell" behavior. Shrink-swell is the cyclic change in volume (expansion and contraction) that occurs in fine-grained clay sediments from the process of wetting and drying. Structural damage may result over a long period of time, usually the result of inadequate soil and foundation engineering or the placement of structures directly on expansive soils. Typically, soils that exhibit expansive characteristics comprise the upper five feet of the surface. The effects of expansive soils could damage foundations of aboveground structures, paved roads and streets, and concrete slabs. Expansion and contraction of soils, depending on the season and the amount of surface water infiltration, could exert enough pressure on structures to result in cracking, settlement, and uplift. Locations of expansive soils are site-specific and can generally be remedied through standard engineering practices.

Settlement

Loose, soft soil material comprised of sand, silt and clay, if not properly engineered, has the potential to settle after a building is placed on the surface. Settlement of the loose soils generally occurs slowly but over time can amount to more than most structures can tolerate. Building settlement could lead to structural damage such as cracked foundations and misaligned or

Table 3.9-1: Characterization of Major Faults in the Southern California Region[5] (Los Angeles, San Bernardino, Riverside, Orange, Imperial, Ventura Counties)				
Class A Faults				
Fault	**Counties**	**Recency**[6]	**Slip Rate (mm/yr)**	**Max. Moment**[7]
San Andreas	Los Angeles, San Bernardino, Riverside, Imperial	Historic	25.0-34.0	7.2-7.5
San Jacinto-Imperial	San Bernardino, Riverside, Imperial	Holocene, Later Quaternary	4.0-20.0	6.6-7.2
Elsinore	Riverside, Imperial	Holocene	2.5-5.0	6.8-7.1
ELSINORE AND SAN JACINTO FAULT ZONES (NON-CLASS A FAULTS)				
Brawley Seismic Zone	Imperial		25.0	6.4
Chino	San Bernardino, Riverside		1.0	6.7
Earthquake Valley	-		2.0	6.5
Elmore Ranch	Imperial		1.0	6.6
TRANSVERSE RANGES AND LOS ANGELES BASIN				
Clamshell-Sawpit	Los Angeles		0.5	6.5

5 Characterization of the faults in Southern California is derived from documents accessible at the California Geological Survey's web page, Probabilistic Seismic Hazard Assessment Maps (PSHA), at: <http://www.consrv.ca.gov/cgs/rghm/psha/index.htm>; see Petersen, et al., 1996. The geographic location of the faults is derived from fault characterizations at the USGS web site for recent earthquake activity at <http://quake.wr.usgs.gov/recenteqs/FaultMaps/118-34.htm>, and also from the list of California and Nevada faults at <http://quake.wr.usgs.gov/info/faultmaps/faultlist.html>.

6 "Recency of fault movement refers to the time period when the fault is believed to have last moved. The age is expressed in terms of the Geologic Time Scale. Generally, the older the activity on a fault, the less likely it is that the fault will produce an earthquake in the near future. For assessing earthquake hazard, usually only faults active in the Late Quaternary or more recently are considered. These include the following three non-overlapping time periods: Historic: Refers to the period for which written records are available (approximately the past 200 years, in California and Nevada).

Holocene: Refers to a period of time between the present and 10,000 years before present. Faults of this age are commonly considered active. For the purpose of classifying faults, C.W. Jennings defined Holocene to exclude the Historic; that is, from 200 to 10,000 years before the present).

Late Quaternary: Refers to the time period between the present and approximately 700,000 years before the present. Here too, for the purpose of classifying faults, Jennings defined Late Quaternary to exclude the Holocene and the Historic."

http://quake.wr.usgs.gov/info/faultmaps/slipage.html

Where no recency data is given, no determination has been made.

7 The Maximum Moment Magnitude is an estimate of the size of a characteristic earthquake capable of occurring on a particular fault. Moment magnitude is related to the physical size of a fault rupture and movement across a fault. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event [CGS, 2002b]. Richter magnitude estimations can be generally higher than moment magnitude estimations.

Table 3.9-1: Characterization of Major Faults in the Southern California Region (cont.) (Los Angeles, San Bernardino, Riverside, Orange, Imperial, Ventura Counties)				
Class B Faults				
Fault	**Counties**	**Recency**	**Slip Rate (mm/yr)**	**Max. Moment**
TRANSVERSE RANGES AND LOS ANGELES BASIN (cont.)				
Cucamonga	San Bernardino		5.0	6.9
Hollywood	Los Angeles		1.0	6.4
Holser	Ventura		0.4	6.5
Malibu Coast	Los Angeles, Ventura		0.3	6.7
Mission Ridge - Arroyo Parida - Santa Ana	Los Angeles		0.4	7.2
Newport-Inglewood	Los Angeles, Orange	Late Quaternary (?)	1.0	7.1
Oak Ridge	Ventura	Holocene, Late Quaternary	4.0	7.0
Palos Verdes	Los Angeles		3.0	7.3
Pleito	-			
Raymond	Los Angeles		1.5	6.5
Red Mountain	San Bernardino		2.0	7.0
San Cayetano	Ventura		6.0	7.0
San Gabriel	Ventura, Los Angeles	Holocene	1.0	7.2
San Jose	San Bernardino, Los Angeles		0.5	6.4
Santa Monica	Los Angeles		1.0	6.6
Santa Ynez (West)	Ventura		2.0	7.1
Santa Ynez (East)	Ventura		2.0	7.1
Santa Susana	Ventura, Los Angeles	Historic, Late Quaternary	5.0	6.7
Sierra Madre (San Fernando)	Los Angeles		2.0	6.7
Sierra Madre	Los Angeles	Holocene, Late Quaternary	2.0	7.2
Simi-Santa Rosa	Ventura		1.0	7.0
Ventura-Pitas Point	Ventura		1.0	6.9
Verdugo	Los Angeles, Ventura		0.5	6.9
White Wolf	-		2.0	7.3
LOS ANGELES BLIND THRUSTS				
Compton thrust	-		1.5	6.8
Elysian Park	-		1.5	6.7
Upper Elysian Park	-		1.3	6.4
Northridge	Ventura, Los Angeles		1.5	7.0
Puente Hills blind thrust	Los Angeles		0.7	7.1
TRANSVERSE RANGES AND MOJAVE				
Fault	**Counties**	**Recency**	**Slip Rate** (mm/yr)	**Max. Moment**
Blackwater	-		0.6	7.1
Burnt Mountain	-		0.6	6.5
Calico-Hidalgo	San Bernardino		0.6	7.3

Table 3.9-1: Characterization of Major Faults in the Southern California Region (cont.) (Los Angeles, San Bernardino, Riverside, Orange, Imperial, Ventura Counties)				
Class B Faults				
Fault	**Counties**	**Recency**	**Slip Rate (mm/yr)**	**Max. Moment**
TRANSVERSE RANGES AND MOJAVE (cont.)				
Cleghorn	San Bernardino		3.0	6.5
Eureka Peak	-		0.6	6.4
Gravel Hills-Harper Lake	San Bernardino		0.6	7.1
Helendale-S. Lockhart	San Bernardino		0.6	7.3
Johnson Valley (Northern)	San Bernardino		0.6	6.7
Landers	-		0.6	7.3
Lenwood - Lockhart-Old Woman Springs	San Bernardino		0.6	7.5
North Frontal Fault zone (Western)	San Bernardino		1.0	7.2
North Frontal Fault zone (Eastern)	San Bernardino		0.5	6.7
Pinto Mountain	San Bernardino		2.5	7.2
Pisgah -Bullion Mountain-Mesquite Lake	San Bernardino		0.6	7.3
S. Emerson-Copper Mountain	San Bernardino		0.6	7.0
- Location data not found Source: California Geological Survey; U.S. Geological Survey				

cracked walls and windows. Settlement problems are site-specific and can generally be remedied through standard engineering applications.

Land Subsidence

Land subsidence is caused by a variety of agricultural, municipal or mining practices that contribute to the loss of support materials within a geologic formation. Agricultural practices can cause oxidation and subsequent compaction and settlement of organic clay soils or hydro-compaction allowing land elevations to lower or sink. Agricultural and municipal practices can result in the overdraft of a groundwater aquifer thereby causing aquifer settlement. Groundwater overdraft occurs when groundwater pumping from a subsurface water-bearing zone (aquifer) exceeds the rate of aquifer replenishment. The extraction of mineral or oil resources can also result in subsidence from removal of supporting layers in the geologic formation. Substantial subsidence occurs in the SCAG region due to groundwater extraction and subsequent lowering of the groundwater surface, typically beneath a confining clay stratum. The impact of subsidence could include lowering of the land surfaces, increased potential for flooding, potential disturbance or damage to buried pipelines and associated structures, and damage to structures designed with minimal tolerance for settlement.

Figure 3.9-4 (see the Figure Chapter at the end of this document) shows areas within the SCAG region susceptible to subsidence.

Landslides

Generally, a slope can fail when its ability to resist movement decreases and the stresses on a slope increase. The material in the slope and external processes such as climate, topography, slope geometry, and human activity can render a slope unstable and eventually initiate slope movements and failures. Factors that decrease resistance to movement in a slope include pore water pressure, material changes, and structure. Changes in slope material such as improperly engineered fill slopes can alter water movement and lead to chemical and physical changes within the slope. Unfavorable fracture or joint orientation and density may develop as a rock material responds to reduced weight or strain relief, resulting in a decreased ability of the rock material to resist movement. Removing the lower portion (the toe) decreases or eliminates the support that opposes lateral motion in a slope. This can occur by man-made activity such as excavations for road-cuts located along a hillside. Over-steepening a slope by removing material can also reduce its lateral support. Placement of buildings on slopes can increase the amount of stress that is applied to a potential failure surface. Shaking during an earthquake may lead materials in a slope to lose some cohesion, cause liquefaction or change pore water pressures. Landslide-susceptible areas within the SCAG region are those with low-strength soil material on hilly topography, for example, the Portuguese Bend and Point Fermin areas of the Palos Verdes Peninsula, and the Blackhawk slide area on the north slope of the San Bernardino Mountains.

Figure 3.9-5 (see the Figure Chapter at the end of this document) shows areas within the SCAG region susceptible to landslides.

The coastal regions of Los Angeles, Orange, and Ventura Counties are susceptible to wave erosion hazards. Coastal erosion is a natural process that is typically the most visible during storm events. Beach sand is replenished by sediment loads in rivers and gentler waves after storm events or during summer months. Erosion rates of one inch per year are considered moderate. However, depending on the severity and duration of storm events and the degree of human intervention with natural coastline or riverine processes, coastal erosion can proceed at considerable rates, resulting in rapid visible coastline recession. In areas of extreme coastal erosion, such as the cities of Rancho Palos Verdes and Malibu, slopes have been undercut by waves during storm events, causing slope failure and resulting in property damage and risks to human health and safety.

The Pacific Ocean borders the Peninsular Range province and the Transverse Range Province on the west. Nearly all the sea cliffs along the coast display some sign of coastal erosion. Coastal retreat is attributable to various processes, including undercutting from wave action, weathering and erosion of rocks and cliffs, emergence of groundwater at the cliff face, rain-wash, and landsliding. Additionally, these naturally occurring forces can be assisted by human activity such as coastal road construction, channelization of surface water flows, or development on marine terraces.

Soil Erosibility

Soil erosion is also a natural on-going process that transports, erodes and displaces soil particles through a transport mechanism such as flowing water or wind. Loose texture and steep slopes primarily result in high wind erosibility potential in soils. Wind erosion is most severe in arid regions where sandy or loamy sediments are unvegetated and exposed to severe wind conditions, such as the eastern portions of San Bernardino, Riverside, and Imperial Counties. Human intervention can accelerate the natural erosion process. For instance, typical consequences of development increase erosion potential from the removal of vegetative cover and reduction of overall permeable area. These activities can lead to increased water runoff rates and concentrated flows that have greater potential to erode exposed soils. The effects of excessive erosion range from nuisance problems that require additional maintenance, such as increased siltation in storm drains, to instances of more severe damage where water courses are down-cut and gullies develop. These processes can eventually undermine adjacent structures or topography. Human activities that disturb soils in arid regions increase wind erosion potential. Many of the desert areas in the SCAG region are also susceptible to blowing sand, a severe form of wind erosion that damages property and accumulates soil on roadways. The majority of the soils in the SCAG region exhibit moderate to high erosion potential, which can be compounded by development.

Figure 3.9-6 (see the Figure Chapter at the end of this document) shows the general location of soils within the SCAG Region which exhibit moderate to high erosion potential.

Seismic Hazards

Movements on the previously identified faults will likely cause future earthquakes in the SCAG region. Earthquakes can originate in areas where potential seismic energy has built up along a fault over time, but has not yet been released in the form of an earthquake. Studies supported by the National Earthquake Hazards Reduction Program enable scientists to evaluate the hazard level in different areas. In Southern California, scientists estimate that the probability of a magnitude 7.0 or greater earthquake by the year 2024 approaches 80 to 90 percent. The four major hazards generally associated with earthquakes are ground shaking, fault surface rupture (ground displacement), liquefaction ground failures, and settlement.

Peak Ground Acceleration

Ground shaking may affect areas hundreds of miles distant from the earthquake's epicenter. Historic earthquakes have caused strong ground shaking and damage in many areas of the SCAG region. The composition of underlying soils in areas located relatively distant from faults can intensify ground shaking. Areas that are underlain by bedrock tend to experience less ground shaking than those underlain by unconsolidated sediments such as artificial fill.

Ground shaking is commonly described in terms of peak ground acceleration as a fraction of the acceleration of gravity (g), or by using the Modified Mercalli Intensity Scale, a common metric for characterizing intensity. The Mercalli Scale is a more descriptive method involving 12 levels of intensity denoted by Roman numerals. As presented in Table 3.9-2, below, Modified Mercalli

Table 3.9-2: Modified Mercalli Intensity Scale[8]
I. Not felt except by a very few under especially favorable conditions.
II. Felt only by a few persons at rest, especially on upper floors of buildings.
III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.
Source: U.S. Geological Survey, National Earthquake Information Center

(MM) intensities range from level I (shaking that is not felt) to level XII (total damage). MM intensities ranging from IV to X could cause moderate to significant structural damage. The degree of structural damage, however, will not be uniform. Not all buildings perform identically in an earthquake. The age, material, type, method of construction, size, and shape of a building all affect its performance.

Earthquakes on the various and potentially active fault systems are expected to produce a wide range of ground shaking intensities in the SCAG region. The estimated maximum moment magnitudes represent characteristic earthquakes on particular faults.[9] While the magnitude is a measure of the energy released in an earthquake, intensity is a measure of the ground shaking effects at a particular location. Shaking intensity can vary depending on the overall magnitude,

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8 Excerpted from <http://neic.usgs.gov/neis/general/mercalli.html>

9 Moment magnitude is related to the physical size of a fault rupture and movement across a fault. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event [California Geological Survey (CGS), 1997]. See Table 3.9-1, pg. 3.9-5, for the moment magnitudes associated with particular faults.

distance to the fault, focus of earthquake energy, and characteristics of geologic media. Generally, intensities are highest at the fault and decrease with distance from the fault.

Figure 3.9-3 (see the Figure Chapter at the end of this document) identifies potential areas of Peak Ground Acceleration.

Surface Fault Rupture

The surface expression of earthquake fault rupture typically occurs in the immediate vicinity of the originating fault. The magnitude and nature of the rupture may vary across different faults, or even along different segments of the same fault.[10] Rupture of the surface during earthquake events is generally limited to the narrow strip of land immediately adjacent to the fault on which the event is occurring. Surface ruptures associated with the 1992 Landers earthquake in San Bernardino County extended for a length of 50 miles, with displacements varying from one inch to 20 feet.

The Alquist-Priolo Earthquake Fault Zoning Act was passed in 1972, to mitigate the risk to human habitation of seismically-induced ground-surface ruptures. This state law was a direct result of the 1971 San Fernando Earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures. Surface rupture is the most easily avoided seismic hazard, provided regulatory stipulations embedded in this law are met.

The law requires the State Geologist to establish regulatory zones (known as Earthquake Fault Zones) around the surface traces of active faults, and to issue appropriate maps.[11] An indicative map of identified Earthquake Fault Zones delineating potential rupture areas is provided in Figure 3.9-3 (see the Figure Chapter at the end of this document). Detailed maps are distributed to all affected cities, counties, and state agencies for their use in planning and controlling new or renewed construction. Local agencies must regulate most development projects within the zones, including all land divisions and most structures intended for human habitation.

Fault surface rupture almost always follows preexisting faults, which are zones of weakness. Rupture may occur suddenly during an earthquake, or slowly in the form of fault creep. Sudden displacements are more damaging to structures because they are accompanied by ground shaking. Fault creep is the slow rupture of the earth’s crust. Not all earthquakes result in surface rupture (e.g., the 1994 Northridge earthquake).

Liquefaction and Ground Failure

Liquefaction is the process by which water-saturated sandy soil materials lose strength and become susceptible to failure during strong ground shaking in an earthquake. The shaking causes the pore-water pressure in the soil to increase, thus transforming the soil from a stable

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[10] California Geological Survey (CGS), *Guidelines for evaluating the hazard of surface fault rupture*, CGS Note 49, 2002a.

[11] "Earthquake Fault Zones" were called "Special Studies Zones" prior to January 1, 1994.

solid to a more liquid form. Liquefaction has been responsible for ground failures during almost all of California's large earthquakes. The depth to groundwater can control the potential for liquefaction; the shallower the groundwater, the higher the potential for liquefaction. Earthquake-induced liquefaction most often occurs in low-lying areas with soils or sediments composed of unconsolidated, saturated, clay-free sands and silts, but can also occur in dry, granular soils, or saturated soils with some clay content.

Four kinds of ground failure commonly result from liquefaction: lateral spread, flow failure, ground oscillation, and loss of bearing strength. A *lateral spread* is a horizontal displacement of surficial blocks of sediments resulting from liquefaction in a subsurface layer. Lateral spread occurs on slopes ranging between 0.3 and 3 percent and commonly displaces the surface by several meters to tens of meters. *Flow failures* occur on slopes greater than 3 degrees and are primarily liquefied soil or blocks of intact material riding on a liquefied subsurface zone. *Ground oscillation* occurs on gentle slopes when liquefaction occurs at depth and no lateral displacement takes place. Soil units that are not liquefied may pull apart from each other and oscillate on the liquefied zone. Ground fissures can accompany ground oscillation and sand boils and damage underground structures and utilities. The *loss of bearing pressure* can occur beneath a structure when the underlying soil loses strength and liquefies. When this occurs, the structure can settle, tip, or even become buoyant and "float" upwards.

Liquefaction potential is a function of the potential level of ground shaking at a given location and depends on the geologic material at that location. Structural failure often occurs as sediments liquefy and cannot support structures that are built on them. Alluvial valleys and coastal regions are particularly susceptible to liquefaction. Unconsolidated alluvial deposits in desert region deposits are rarely saturated because of the depth to the water table and are thus less susceptible to liquefaction than unconsolidated alluvium adjacent to stream channels.

Earthquake-Induced Subsidence

Settlement of the ground surface can be accelerated and accentuated by earthquakes. During an earthquake, settlement can occur as a result of the relatively rapid compaction and settling of subsurface materials (particularly loose, non-compacted, and variable sandy sediments) due to the rearrangement of soil particles during prolonged ground shaking. Settlement can occur both uniformly and differentially (i.e., where adjoining areas settle at different rates). Within the SCAG region, artificial fills, unconsolidated alluvial sediments, slope washes, and areas with improperly engineered construction-fills typically underlie areas susceptible to this type of settlement.

Seismically-Induced Landslides

Strong ground shaking during earthquake events can generate landslides and slumps in uplands or coastal regions near the causative fault. Seismically-induced landsliding has typically been found to occur within 75 miles of the epicenter of a magnitude 6.5 earthquake.

Seismically-induced landslides would be most likely to occur in areas that have previously experienced landslides or slumps, in areas of steep slopes, or in saturated hillside areas. Areas of the SCAG region are susceptible to seismically-induced landsliding because of the abundance of active faults in the region and the existing landslide hazards. (See Figure 3.9-5, in the Figure Chapter at the end of this document.)

Earthquake-Induced Inundation

Because California and the West Coast of the United States are seismically active, California is subject to flood hazard from tectonic activity capable of generating submarine earthquakes, volcanic eruptions, and landslides. Considering its proximity to the Pacific Ocean, the inundation by tsunamis (seismic sea waves) or seiches (oscillating waves in enclosed water bodies) can occur along the California coast in the event of significant earthquake. For purposes of a relative comparison, an earthquake with its epicenter in Alaska and with a magnitude of 8.5 (Richter scale) generated a seismically induced sea wave with a maximum wave height of 11 feet in the Monterey Harbor, on the central coast of California north of the SCAG region.

REGULATORY SETTING

The regulatory setting describes the federal, state, and local agencies that have jurisdiction over geology, soils, and seismicity. The regulations pertinent to these areas that each of these agencies enforce are also described.

Federal Agencies and Regulations

U.S. Department Of Agriculture, Natural Resources Conservation Service (NRCS)

The NRCS maps soils and farmland uses to provide comprehensive information necessary for understanding, managing, conserving and sustaining the nation's limited soil resources. In addition to many other natural resource conservation programs, the NRCS manages the Farmland Protection Program, which provides funds to help purchase development rights to keep productive farmland in agricultural uses. Working through existing programs, USDA joins with State, tribal, or local governments to acquire conservation easements or other interests from landowners.

State Agencies and Regulations

California Department of Conservation

In 1982, the State of California created the Farmland Mapping and Monitoring Program within the California Department of Conservation to carry on the mapping activity from the NRCS on a continuing basis. The California Land Conservation Act of 1965, also known as the Williamson Act, is designed to preserve agricultural and open space lands by discouraging their premature and unnecessary conversion to urban uses. Williamson Act contracts, also known as agricultural preserves, offer tax incentives for agricultural land preservation by ensuring that land will be assessed for its agricultural productivity rather than its highest and best uses.

California Building Code

The *California Building Code* is another name for the body of regulations contained in Title 24, Part 2, of the California Code of Regulations, which is a portion of the California Building Standards Code (CBSC, 1995). Title 24 is assigned to the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under state law, all building standards must be centralized in Title 24 or they are not enforceable (Bolt, 1988). Published by the International Conference of Building Officials, the Uniform Building Code (UBC) is a widely adopted model building code in the United States. The California Building Code incorporates by reference the UBC with necessary California amendments. About one-third of the text within the California Building Code has been tailored for California earthquake conditions. Although widely accepted and implemented throughout the United States, local, city and county jurisdictions can adopt the UBC either in whole or in part.

Alquist-Priolo Special Study Zones

The Alquist-Priolo Earthquake Fault Zoning Act of 1971 requires that special geologic studies be conducted to locate and assess any active fault traces in and around known active fault areas prior to development of structures for human occupancy. This state law was a direct result of the 1971 San Fernando Earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures.

The Alquist-Priolo Act’s main purpose is to prevent the construction of buildings used for human occupancy on the surface trace of active faults. This Act addresses only the hazard of surface fault rupture and is not directed toward other earthquake hazards.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act of 1990 addresses non-surface fault rupture earthquake hazards, including liquefaction and seismically-induced landslides. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act.

California Department of Transportation (Caltrans)

Caltrans’ jurisdiction includes rights-of-way of state and interstate routes within California. Any work within the right-of-way of a federal or state transportation corridor is subject to Caltrans’ regulations governing allowable actions and modifications to the right-of-way. Caltrans issues permits to encroach on land within their jurisdiction to ensure encroachment is compatible with the primary uses of the State Highway System, to ensure safety, and to protect the State’s investment in the highway facility. The encroachment permit requirement applies to persons, corporations, cities, counties, utilities, and other government agencies. A permit is required for specific activities including opening or excavating a state highway for any purpose, constructing or maintaining road approaches or connections, grading within rights-of-way on any state highway, or planting or tampering with vegetation growing along any state highway. The encroachment permit application requirements relating to geology, seismicity and soils include information on road cuts, excavation size, engineering and grading cross-sections, hydraulic calculations, and mineral resources approved under the state Surface Mining Area Reclamation Act (SMARA).

Local Agencies and Regulations

General Plans and Seismic Safety Element

City and county governments typically develop as part of their General Plans, safety and seismic elements that identify goals, objectives, and implementing actions to minimize the loss of life, property damage and disruption of goods and services from man-made and natural disasters including floods, fires, non-seismic geologic hazards and earthquakes. General Plans can provide policies and develop ordinances to ensure acceptable protection of people and structures from risks associated with these hazards. Ordinances can include those addressing unreinforced masonry construction, erosion or grading.

METHODOLOGY

This section summarizes the methodology used to evaluate the expected impacts associated with geology, soils, seismicity.

The transportation projects and growth projections for the year 2030 are regional, cumulative, and long-term in nature, and provide a conservative estimate of potential environmental impacts.

Comparison with the No Project

The analysis of geology, soils, and seismicity includes a comparison between the expected future conditions with the proposed Plan and the expected future conditions if no Plan were adopted. This evaluation is not included in the determination of the significance of impacts; however, it provides a meaningful perspective on the benefits and effects of the 2004 RTP.

Determination of Significance

The methodology for determining the significance of these impacts compares the existing conditions to expected future conditions with the Plan, as required in CEQA Guidelines Section 15126.2(a). The assessment of geologic impacts was performed by overlaying data in GIS format on the location of areas known to pose seismic or geologic hazards. Specifically, the proposed projects and associated growth of the proposed Plan were plotted on maps that identify potential hazards, such as known faults, high ground acceleration areas, areas exhibiting landslide potential, areas of potential subsidence, and areas with highly erodible soils in the SCAG region. A 300-foot-wide buffer, 150 feet to either side, was projected along all transportation project segments, and taken as a reasonable estimate of land area likely to be directly disturbed by projects considered in the 2004 RTP. The GIS data was then used to determine the proximity of proposed projects, and any associated growth, to potential geologic constraints or features.

SIGNIFICANCE CRITERIA

Criteria for determining significance of impacts were developed from the CEQA Guidelines Appendix G. The proposed Plan may have a significant impact if its implementation would potentially:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
    - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist, or based on other substantial evidence of a known fault [refer to CGS's Special Publication 42];
    - Strong seismic ground shaking;
    - Seismic-related ground failure, including liquefaction;
    - Landslide;
- Result in substantial soil erosion or the loss of topsoil;
- Locate transportation projects on, or facilitate growth to occur on, strata or soil that are unstable, or that would become unstable as a result of the project, such as expansive soils, and potentially result in on- or off-site landslides, lateral spreading, subsidence, liquefaction, or collapse, creating substantial risks to life or property;
- Result in cumulatively considerable adverse effects on human beings.

IMPACTS AND MITIGATION MEASURES

A summary of the potential impacts of geologic and seismic hazards on proposed regional transportation projects is presented in Table 3.9-3, below. A more detailed discussion of the impacts and the potential mitigation measures follows the table.

All mitigation measures shall be included in project-level analysis, as appropriate. The lead agency for each individual project in the Plan shall be responsible for ensuring adherence to the mitigation measures prior to construction. SCAG shall be provided with documentation of compliance with mitigation measures through its Intergovernmental Review Process.

Impact 3.9-1: Seismic events can damage transportation infrastructure through surface rupture, ground shaking, liquefaction, and landsliding. In addition, seismically induced tsunami and seiche waves can damage transportation infrastructure proximate to coastal areas. Potential impacts to property and public safety from seismic activity would be

Table 3.9-3: Potential Impacts of Seismic and Geologic Hazards On Regional Transportation Projects (By County)

Project	Ground Acceleration	Erosion	Subsidence	Landslide	Liquefaction[12]
Imperial County					
SR 98	X	X			NA
SR 111	X	X			NA
SR 115	X				NA
Los Angeles County					
I 5	X		X		X
I 10	X	X		X	X
I 405			X		X
I 710	X	X			X
SR 14	X	X	X	X	X
SR 30	X	X		X	X
SR 60				X	X
SR138	X	X			
BRT	X		X		
Light Rail	X		X		
Metrolink	X	X		X	
Transitway	X				X
Freight Rail			X	X	
Orange County					
I 5		X		X	X
I 405					X
SR 22			X		
SR 55					X
SR 57			X	X	X
SR 73		X		X	X
SR 91			X	X	X
SR 241		X		X	X
BRT		X			X
Centerline Rail		X			X
Freight Rail			X	X	X
Riverside County					
Ramona/Cajalco Expressway	X			X	NA
I 15	X	X		X	NA
I 215	X			X	NA
SR 60	X	X			NA
SR 74		X		X	NA
SR 79	X	X		X	NA
SR 91	X	X			NA
Metrolink	X			X	NA
Freight Rail	X	X		X	NA
San Bernardino County					
I 10	X	X			NA
I 15	X	X		X	NA
I 215	X	X			NA
SR 18		X		X	NA
SR 30	X	X			NA
SR 60	X	X			NA
SR 138	X	X		X	NA
US 395	X	X		X	NA
Light Rail	X	X			NA
Metrolink	X	X			NA
Freight Rail	X	X		X	NA
Ventura County					
SR 23	X			X	X
SR 118	X		X	X	X
US 101				X	X
Metrolink	X	X	X		X

Source: SCAG; California Division of Mines and Geology; Southern California Earthquake Center; U.S. Department of Agriculture STATSGO Database; California Department of Conservation.

12 Liquefaction potential data was not available, at the time of this analysis, for Imperial, Riverside, and San Bernardino Counties.

considered significant in some cases. The proposed mitigation measures would reduce this impact to less than significant levels.

The entire SCAG region is susceptible to impacts from seismic activity. Numerous active faults are known to exist in the region that could potentially generate seismic events capable of significantly affecting existing and proposed transportation facilities. As such, new transportation facilities would be exposed to both direct and indirect effects of earthquakes. Potential effects from surface rupture and severe ground shaking could cause catastrophic damage to transportation infrastructure, particularly overpasses and underground structures.

The 2004 RTP includes highway, arterial, and public transit projects throughout the SCAG region. The highway and arterial projects mostly include widening existing highways and constructing new interchanges. A few projects involve constructing new highway segments including auxiliary capacity enhancement facilities and mixed flow connectors. New rail lines proposed in the 2004 RTP include the Gold Line extension from Pasadena to Montclair in San Bernardino, the Exposition Light Rail Line from downtown Los Angeles to Santa Monica, the Green Line extension to the LAX airport, the Centerline light rail project in Orange County, and the Metrolink extensions throughout the region. The proposed Maglev system would traverse the urbanized area of the SCAG region primarily within the rights-of-way for existing freeway corridors. All the existing highways and rail lines in the SCAG region are subject to seismic or geologic influences to some degree. Similarly, new bus rapid transit (BRT) routes and goods movement (freight) rail routes proposed in the 2004 RTP on existing roadways and railways would each be susceptible to seismic or geologic impacts for at least some portion of their length.

Many proposed projects would be located within or across Alquist-Priolo Fault Zones. These zones are identified as areas directly over faults that are susceptible to surface rupture. (See Figure 3.9-3 in the Figure Chapter at the end of this document.) The Maglev transit system would cross numerous Alquist-Priolo Zones including the San Andreas Fault Zone. Other projects would be located in areas known to experience severe ground acceleration during earthquakes. These areas would be susceptible to severe ground shaking and earth movement. Other projects would be located on soils prone to liquefaction or in landslide-prone areas. Table 3.9-3, above, lists highway corridors, by county, for which construction projects have been proposed near areas of known seismically-induced severe ground acceleration, subsidence, landslide, or liquefaction potential. In addition to direct impacts on transportation infrastructure, seismic events could damage ancillary facilities such as port facilities, traffic control equipment, and train stations. These indirect impacts could promote additional delays and breaks in service while repairs are made.

The CGS, pursuant to the Sesimic Hazards Act of 1990, has begun preparing seismic hazard maps of the southern California region. These maps identify areas with high potential for exhibiting liquefaction. At this time only a portion of the SCAG region has been mapped. Therefore, specific information on areas prone to liquefaction or seismically induced landsliding is not yet available for each of the proposed projects. The potential for projects to be significantly affected by liquefaction would be higher in areas exhibiting shallow groundwater levels and unconsolidated soils such as fill material, some alluvial soils, and coastal sands.

As with the 1994 Northridge Earthquake, earthquakes can occur within previously undetected fault zones. As such, the potential exists for severe earthquakes to occur in unexpected locations throughout the SCAG region. Given the ubiquity of the transportation infrastructure in the region, future seismic activity from previously unknown faults could present catastrophic impacts to the network. Similarly, liquefaction potential can change over time in heavily landscaped areas such as parks and agricultural areas, as groundwater levels are altered.

Although seismic activity can cause damage to existing substandard construction, new designs taking account of current engineering knowledge can significantly reduce potential damage and harm. Earthquake-resistant designs employed on new structures minimize the impact to public safety from seismic events. As such, 2004 RTP projects that employ design standards which consider seismically active areas would reduce their potential for significant impacts.

Impacts from tsunamis would be isolated to the coastal regions. None of the proposed new highway or transit projects would be susceptible to inundation by tsunami, given their distance from the coast. Local jurisdictions provide guidance for tsunamis along coastal areas. For example, the City of Los Angeles General Plan Framework identifies a 12-foot run-up potential from a severe tsunami wave. Although building within this zone is not prohibited, certain early warning and emergency egress route systems are encouraged. Seiche waves could potentially over-top dam structures in the region and inundate low lying areas. Local water agencies, the State Department of Water Resources, and the federal Bureau of Reclamation are responsible for ensuring dam safety in the region including those from seismic events. Structural considerations have been included in each dam in the region to reduce potential failure. Due to remote potential for the occurrence of tsunamis or seiche waves and the general oversight of management agencies, the effects on transportation infrastructure would not be considered significant.

Mitigation Measures

MM 3.9-1a: Implementing agencies shall ensure that projects are designed in accordance with county and city code requirements for seismic ground shaking. The design of projects shall consider seismicity of the site, soil response at the site, and dynamic characteristics of the structure, in compliance with the appropriate California Building Code standards for construction in or near fault zones.

MM 3.9-1b: Implementing agencies shall ensure that projects located within or across Alquist-Priolo Zones comply with design requirements provided in Special Publication 117, published by the CGS[13], as well as relevant local, regional, state, and federal design criteria for construction in seismic areas.

MM 3.9-1c: The project implementing agencies shall ensure that geotechnical analysis is conducted within construction areas to ascertain soil types and local faulting prior to preparation of project designs.

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13 See: <http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp>

Significance After Mitigation

Less than significant.

Impact 3.9-2: Highway and rail construction can require significant earthwork and road cuts, increasing long-term erosion potential and slope failure. Earthwork can also alter unique geologic features. The impacts of projects considered as part of the 2004 RTP would be considered significant in some cases.

Several projects proposed in the 2004 RTP would involve substantial construction of new facilities such as rail lines and highway segments within previously undisturbed areas. Some of these projects could require significant earth work or cuts into hillsides which can become unstable over time. Road cuts can expose soils to erosion over the life of the project, creating potential landslide and falling rock hazards. Engineered roadways can be undercut over time by stormwater drainage and wind erosion. Some areas would be more susceptible to erosion than others due to the naturally occurring soils with high erosion potential. Other projects on steep grades or winding mountain passes, such as along State Route 14 in Los Angeles County and Interstate 15 in San Bernardino County, would pose the greatest potential impacts. Table 3.9-3, above, lists the highways on which proposed projects would be located in areas with moderate or high erosion potential.

Notwithstanding natural soil types, engineered soils can also erode due to poor construction methods and design features or lack of maintenance. Appropriate construction methods, earthwork design, and road cut design can reduce this potential impact to less than significant levels.

New roadways can also permanently alter unique geologic features, particularly in canyons, coast lines, and mountain passes. However, most of the projects proposed in the 2004 RTP would occur in urbanized portions of the SCAG region or in existing transportation corridors. Nonetheless, new lanes along State Route 14 (SR-14), Interstate 405 (I-405), and I-15 may require earthwork that would impact existing natural geologic features.

Mitigation Measures

MM 3.9-2a: The project implementing agencies shall ensure that project designs provide adequate slope drainage and appropriate landscaping to minimize the occurrence of slope instability and erosion. Design features shall include measures to reduce erosion from stormwater. Road cuts shall be designed to maximize the potential for revegetation.

MM 3.9-2b: Implementing agencies shall ensure that projects avoid landslide areas and potentially unstable slopes wherever feasible.

MM 3.9-2c: Where practicable, routes and project designs that would permanently alter unique geologic features shall be avoided.

Significance After Mitigation

Given the topography, ecology and meteorology of the SCAG region, long-term erosion and the potential for slope-failure will remain **significant**.

Impact 3.9-3: Local geology can affect transportation infrastructure. Potentially significant impacts to property and public safety could occur due to subsidence and the presence of expansive soils. Mitigation measures would reduce these impacts to less than significant levels.

Subsidence has historically occurred within the SCAG region due to groundwater overdraft and petroleum extraction. Unconsolidated soils containing petroleum or groundwater often compress when the liquids are removed, causing the surface elevation to decrease. Improperly abandoned oil wells or underground hard rock mining can also cause localized subsidence. Areas of historic subsidence within the SCAG region exist in the Santa Clara River Valley and in the historic oil and gas fields of Los Angeles County including the Baldwin Hills, Long Beach, and Puente Hills areas. The Port of Long Beach has also experienced subsidence due to the placement of fill along the original coast-line. Table 3.9-3, above, lists the highways and new rail lines on which projects are proposed in areas of historic subsidence.

Subsidence can also occur in areas with unconsolidated soils that have not historically shown elevation changes. Transportation infrastructure designs must include appropriate reinforcement to minimize potential impacts from subsidence in areas where such activity has not been witnessed.

In addition, soils with high percentages of clay can expand when wet, causing structural damage to surface improvements. These clay soils can occur in localized areas throughout the SCAG region, making it necessary to survey project areas extensively prior to construction. Each new project location would have the potential to contain expansive soils, although they are more likely to be encountered in lower drainage basin areas.

Expansive soils are generally removed during foundation work to avoid structural damage. Many of the projects proposed in the 2004 RTP would occur within existing transportation corridors, where expansive soils may be expected to have already been removed. New freeways such as the I-710 extension and new rail lines such as the Gold Line Extension from Pasadena to Montclair, and the Green Line Extension near LAX could potentially encounter expansive soils.

Mitigation Measures

MM 3.9-3a: Implementing agencies shall ensure that geotechnical investigations are conducted by a qualified geologist to identify the potential for subsidence and expansive soils. Recommended corrective measures, such as structural reinforcement and replacing soil with engineered fill, shall be implemented in project designs.

MM 3.9-3b: Implementing agencies shall ensure that, prior to preparing project designs, new and abandoned wells are identified within construction areas to ensure the stability of nearby soils.

Significance After Mitigation

Less than significant.

Cumulative Impact 3.9-4: The actions considered by the 2004 RTP have the potential to cause cumulatively considerable adverse effects on human beings, when considered at the regional scale.

Given the ubiquitous distribution of potentially hazardous geological and seismic factors in Southern California, and given the regional scale of transportation projects and programs considered as part of the 2004 RTP, when taken along with the urban form implications of these proposals, the cumulative impacts of the 2004 RTP on geological and seismic factors would be significant.

Mitigation Measures

The project-level mitigation measures (MM 3.9-1 to MM 3.9-3) specified in the three impact categories discussed above, are expected, generally, to provide some measure of additive relief from the potential hazards due to geologic and seismic factors. In addition, the regional-scale planning and growth visioning activities carried out by SCAG in preparation of the 2004 RTP are expected to heighten awareness, particularly among county and city agencies, of the importance of appropriate siting decisions. As can be read from the maps used in this analysis, while it is meaningful to speak of the ubiquity of seismic and geologic hazards throughout the SCAG region, it is also notable that many of the hazards are highly localized. Appropriate use of engineering technologies, when coupled with well thought-out siting decisions, can considerably lessen the potential for harm to human life and property resulting from these factors, taken together.

Significance After Mitigation

Despite the inclusion of the proposed mitigation measures, the cumulative impact remains **significant**.

References

Bates, R.L., Jackson, J.A., *Dictionary of Geological Terms,* prepared American Geological Institute, published Garden City, New York, 1984.

Bolt, B., *Earthquakes,* W. H. Freeman and Company, New York, New York, 1988.

California Building Standards Commission, (CBSC), *California Building Code, Title 24, Part 2*, 2001.

California Geological Survey (CGS), *Guidelines for Evaluating and Mitigating Seismic Hazards in California*, CDMG Special Publication 117, 1997 (Last Updated: 05/28/02). Accessed November 14, 2003, <http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp>

California Geological Survey (CGS), *Guidelines for Evaluating the Hazard of Surface Fault Rupture*, CGS Note 49, 2002a. Accessed November 14, 2003, <http://www.consrv.ca.gov/CGS/information/publications/cgs_notes/note_49/note_49.pdf>

California Geological Survey (CGS), *How Earthquakes and Their Effects Are Measured*, CGS Note 32, 2002b. Accessed November 14, 2003, <http://www.consrv.ca.gov/cgs/information/publications/cgs_notes/note_32/note_32.pdf>

California Geological Survey, *Probabilistic Seismic Hazard Assessment (PSHA) Maps*, 2003a. Accessed November 13, 2003, <http://www.consrv.ca.gov/cgs/rghm/psha/index.htm>

California Geological Survey, *Alquist-Priolo Earthquake Fault Zones*, 2003b. Accessed November 14, 2003, <http://www.consrv.ca.gov/CGS/rghm/ap/>.

California Geological Survey, *Seismic Hazard Mapping Program*, 2003c. Accessed November 18, 2003, <http://gmw.consrv.ca.gov/shmp/>.

Dolan, J.F., Christofferson, S.A. and Shaw, J.H., "*Recognition of Paleoearthquakes on the Puente Hills blind thrust fault, California,*" *Science*, April 4 2003: 115-118.

EQE International, 1994, "*The January 17, 1994 Northridge, CA Earthquake: An EQE Summary Report,* March 1994." Accessed on November 19, 2003 <http://www.eqe.com/publications/northridge/northridge.html>

Jennings, C.W., 1994, *Fault activity map of California and adjacent areas, with locations and ages of recent volcanic eruptions*: California Division of Mines and Geology, Geologic Data Map No. 6, map scale 1:750,000.

McFarling, U.L., 2003, "Major Threat Seen in L.A. Quake Fault," *Los Angeles Times*, April 4, 2003. Accessed on April 10, 2003 <http://www.latimes.com/news/science/la-sci-fault4apr04010421,1,2921477.story?coll=la%2Dnews%2Dscience> ["Puente Hills system could touch off a 7.5 temblor directly beneath downtown. The good news? It might be thousands of years away."]

Norris, R.M. and Webb, R.W. 1976. *Geology of California*, Second Edition, John Wiley and Sons, publisher.

Oakeshott, Gordon B. 1978. *California's changing landscapes*, McGraw-Hill Publishing Company.

Petersen, M.D., Bryant, W.A., Cramer, C.H.*, Probabilistic seismic hazard assessment for the State of California*, California Department of Conservation, Division of Mines and Geology Open-File Report issued jointly with U.S. Geological Survey, CDMG 96-08 and USGS 96-706, 1996. Accessed on November 13, 2003, <http://www.consrv.ca.gov/cgs/rghm/psha/ofr9608/index.htm>

Southern California Association of Governments. November 2003. *2004 RTP draft*.

United States Department of Agriculture, Natural Resource Conservation Service (NRCS). 1967. *Report and generalized soil map, Los Angeles County, California.* Issued June, 1967.

United States Department of Agriculture, Natural Resource Conservation Service (NRCS). 1970. *Soil survey of ventura area, California.* Issued April, 1970.

United States Department of Agriculture, Natural Resource Conservation Service (NRCS). 1978. *Soil survey of Orange County and western part of Riverside County, California.* Issued September, 1978.

United States Department of Agriculture, Natural Resource Conservation Service (NRCS). 1986. *Soil Survey of San Bernardino County, California.* Issued 1986.